The unsettled question: butter or margarine?

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In *The New York Times* of December 11, 1960, the American Heart Association stated: "Reduction or control of fat consumption under medical supervision with reasonable substitution of polyunsaturated for saturated fats is recommended as a possible means of preventing atherosclerosis and decreasing the risk of heart attacks and strokes." This statement was made in the light of the numerous reports showing a close relationship between dietary fat, serum cholesterol levels and the incidence of atherosclerosis.

The reader will recall that fatty acids occurring in nature may be classified as follows:

(1) *Saturated fatty acids (S):* Contain no double bonds, the most important one being palmitic acid which is widely distributed in nature and may contribute 10 to 50% of total fatty acids in any fat.

(2) *Unsaturated fatty acids:* (a) With one double bond, e.g. oleic acid; (b) with two or more double bonds [polyunsaturated (P)], e.g. linoleic acid, linolenic acid, and arachidonic acid.

The degree of unsaturation in any fat plays an important part in determining its physical nature. Fats consisting predominantly of saturated fatty acids (butter) are solid at room temperature, while those with a large proportion of unsaturated fatty acids (vegetable and fish oils) are usually liquid.

The iodine number is a measure of the degree of unsaturation of a fat, based on its ability to take up iodine in the presence of iodine monobromide or monochloride, depending on the number of double-bonds. Iodine number is the amount (in grams) of iodine absorbed by 100 g. of fats.

Although diet is but one etiological factor implicated in the complex pathogenesis of atherosclerosis, the effect of dietary fats upon plasma lipids is now well documented. Most vegetable-seed oils (safflower, corn, sunflower, etc.) and a few marine oils of mammals are rich in polyunsaturated fatty acids and exhibit a cholesterol-reducing action in normal subjects as well as in hypercholesterolemics. On the other hand, the highly saturated animal fats (butter, milk, eggs, etc.) and a few vegetable oils (coconut oil, cocoa butter, palm oil) tend to elevate blood cholesterol. Table I lists the usual dietary sources of saturated and unsaturated fatty acids. From a practical point of view, the statement of the American Heart Association implies the recommendation of a reduction in the intake of animal fats (meat, eggs and dairy products) with a concurrent increase in the consumption of vegetable fats and oils or their derivatives, such as margarines and shortenings. Examples of such modified fat diets have been suggested by the A.M.A. Council on Foods and Nutrition.[1] This sole modification in the fat-eating pattern does not affect the total amount of dietary fat but does affect the P/S ratio (polyunsaturated to saturated fatty acids). This ratio, according to numerous workers, is the crucial factor responsible for the elevation or reduction of blood cholesterol. A P/S ratio of 1.25 and above is considered satisfactory for the effective

TABLE I
Dietary sources of saturated and unsaturated fatty acids

I—Fats rich in polyunsaturated fatty acids	*II—Fats rich in saturated fatty acids*
Vegetable oils	*Vegetable fats*
1. Safflower oil	1. Coconut oil
2. Sunflower oil	2. Palm oil
3. Corn oil	3. Cocoa butter
4. Cottonseed oil	
5. Peanut oil	
Marine oils	*Animal fats*
1. Pilchard oil	1. Meat
	2. Dairy products
	3. Eggs

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reduction or prevention of hypercholesterolemia.

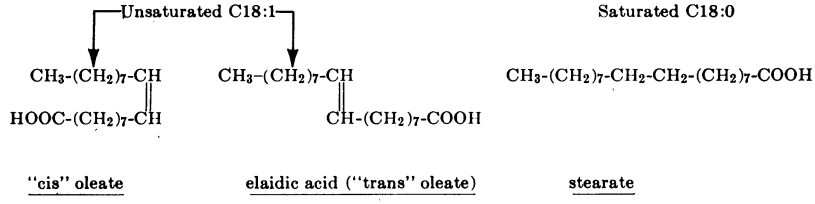
By simply reducing the intake of saturated fats it is also possible to attain such a P/S ratio, but it should be admitted that such a diet is impractical and difficult to follow since meats, eggs and dairy products, which occupy a prominent place in our food habits, have to be drastically reduced. On the other hand, increasing the intake of unsaturated fats in the form of oils or margarines, without reducing the saturated fats, will indeed increase the P/S ratio but will also lead to an undesirable weight gain from these extra fat calories. Since it is well recognized that weight control is an important factor in the prevention and/or management of heart disease, supplementation of the usual diet with unsaturated oils in one form or another cannot be justified. In summary, a diet which is calorically adequate to maintain or attain ideal weight and which provides no more than 40% of the calories as fat with a P/S ratio of 1.25 or more can be termed a "preventive" diet.

However, it should be emphasized that not all polyunsaturated fatty acids contribute to the P/S ratio. Unnatural and conjugated isomers of polyunsaturated fatty acids are excluded from the calculation of this ratio for reasons to be discussed in the present paper. Although these isomers are present only in small amounts in natural fats, they become quantitatively important in certain hydrogenated products, such as margarines and shortenings.

The tremendous increase in margarine consumption in the last decade, for economic reasons and also in response to medical advice and commercial advertising, warrants a reassessment of the nutritional value of margarine compared to butter or oils, from the standpoint of preventing atherosclerosis.

It is our belief that too little is known about the various types of margarines available on the market, their content of polyunsaturated fat and consequently their comparative value. Margarines vary widely in their composition and properties, depending on their constituent oil or oils and on the process of fabrication.

TABLE III
Spatial arrangement of geometric isomers of oleate as compared to stearate



Margarines: Composition and hydrogenation process

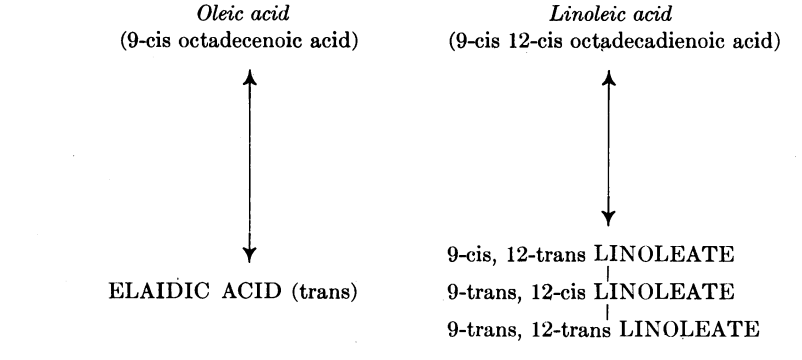
Most margarines are composed of fat (80%), non-fat milk solids, water, a colouring agent (optional) and supplements of vitamins A and D (optional).

They consist essentially of vegetable oils which have been subjected to a more or less extensive hydrogenation. The main object of hydrogenation is to improve the organoleptic qualities of the natural oil or oils and to yield a product comparable to butter. Hydrogenation transforms a liquid oil into a plastic fat at room temperature, improves the taste of the product and renders it more resistant to degradation. Industrial hydrogenation implies the addition of hydrogen atoms to the fatty acid molecule in the presence of heat and a catalyst, generally nickel. Many double-bonds are reduced, which accounts for the higher melting point of a margarine compared to the initial oil. In addition to partial saturation of unsaturated fatty acids, the process of hydrogenation gives rise to a few positional and conjugated isomers of unsaturated fatty acids and partially converts the natural "cis" isomers to "trans" unsaturated fatty acids. The possible geometric isomers of oleic and linoleic acids appear in Table II.

In the "cis" form, the molecule is folded on one side of the double-bond and its length is then ultimately of the same magnitude as the corresponding saturated fatty acid, as shown in Table III.

The degree of saturation (indicated by the iodine value), the P/S ratio and the amount of "trans" isomers of margarines depend on the type of oil or oils and the method of hydrogenation used in their industrial fabrication.

TABLE II
Geometrical isomers of oleic and linoleic acids



Methods of preparation of margarines

There are several ways to hydrogenate vegetable oils in the process of industrial preparation of margarines. The technique most commonly used because it is the cheapest consists in a partial hydrogenation of the entire oil with the consequence that its chemical and nutritional qualities are altered. Most ordinary margarines available on the Canadian market are of this type.

A second method consists of blending 10 to 25% of completely hydrogenated oil with 75 to 90% of non-hydrogenated oil. This method yields a product with a very high melting point but with poor organoleptic qualities. In order to improve the quality of the product obtained by this method the process can be followed by an ester-interchange reaction between the hydrogenated component and the unaltered oil; although the organoleptic qualities of the oil hydrogenated in this way are improved, the fatty acid composition is similar to that of the product obtained without further chemical processing.

The last and undoubtedly the best method consists of blending 40 to 60% of the native oil with 60 to 40% of a partially hydrogenated fraction. This is the method recommended by the Food and Nutrition Board of the American Academy of Sciences in the United States, and most vegetable margarines in the United States are prepared according to it. Unfortunately, in Canada, to our knowledge, only one margarine* is blended according to these recommendations. All the polyunsaturated fatty acids of the hydrogenated fraction are reduced to monounsaturated fatty acids. No abnormal isomers are present in margarines and shortenings so processed, except positional and "trans" isomers of oleic acid, which are well metabolized. The polyunsaturated fatty acid content is markedly greater in products made by this last method; for example, the P/S ratio (polyunsaturated fatty acids: saturated fatty acids) is 1.7, as compared to 0.8 for most margarines produced according to other methods. The iodine value (the lower the value, the greater the saturation) of such a margarine is 90 to 95 compared to 72 to 85 for regular margarines,[2] 30 to 40 for butter and 125 for liquid corn oil.

In addition to the degree of saturation, "trans" fatty acid content varies widely among margarines and depends upon the extent of hydrogenation. Whereas regular margarines (partial hydrogenation of the entire oil) may contain as much as 42% "trans" glycerides,[2, 3] only minimal amounts of these unnatural isomers can be detected in margarines produced by blending native oil with a partially hydrogenated fraction. These unnatural isomers are not included in the calculation of the P/S ratio since they seem to have lost some of the biological properties of the natural 9,12-Cis linoleic acid.

*Marketed as Fleischmann's margarine.

"Trans" fatty acids

Long-term studies indicate that "trans" fatty acids are not toxic to animals nor presumably to humans.[4, 5] They are absorbed and metabolized via the same pathways as the corresponding "cis" isomers.[6-8] However, "trans" polyunsaturated fatty acids (e.g. "trans" linoleate) seem to be more available as energy sources than their "cis" isomers,[9] probably because they exhibit no "essential fatty acid activity", as has been shown by many workers.[8, 10-13] Nevertheless, "trans" fatty acids do not interfere with the proper utilization of the essential "cis" linoleate. Moreover, there is some evidence that "trans" fatty acids might behave more like saturated than unsaturated acids in the pattern of their incorporation into body lipids.[14-17] This can well be explained on the basis of the spatial configuration of "trans" acids, which is almost identical with that of saturated fatty acids as opposed to unsaturated fatty acids.

Margarines and blood cholesterol

It is now widely accepted that the hypocholesterolemic action of a vegetable oil is related to the degree of unsaturation of its component fatty acids, and we know that hydrogenation of vegetable oil reduces its polyunsaturated fatty acid content. Therefore, it is reasonable to suspect that margarines or shortenings may have lost some of the potency of the natural oil because of the higher degree of saturation which occurs in the course of hydrogenation. In addition, the conversion of "cis" polyunsaturated fatty acids to their "trans" isomers may further decrease the P/S ratio and the cholesterol-lowering properties of the original oils. In fact, a few reports indicate a slight trend towards increased plasma cholesterol levels in rabbits fed a concentrated mixture of geometric isomers of linoleate or elaidate.[18, 19] The hypothesis of Spritz and Mishkel[20] may provide an explanation for such findings. According to these workers, the lipid-lowering effect of the polyunsaturated dietary fats is related to the configuration of the molecule. Since the unsaturated fatty acids occupy a greater area than saturated acids, fewer molecules can be accommodated by the apoprotein of the "low-density lipoproteins", and consequently the lipid content of the lipoprotein is lowered. On the other hand, saturated molecules, which spread on a horizontal plane, increase the binding power of the apoprotein; as a result the lipid content of the lipoprotein is increased, and so are plasma lipids. "Trans" fatty acids could therefore affect plasma cholesterol in a way similar to saturated fatty acids, since their spatial structure is comparable.

Reports on the effects of feeding hydrogenated fats on plasma cholesterol are still controversial. Whereas many authors[21-26] notice a slight cholesterol-elevating effect of margarines and hydrogenated oils, Ahrens[27] obtained conflicting results in two subjects. On the other hand, McOsker *et al.*[28] failed to detect any appreciable rise in serum cholesterol in subjects given hydrogenated vegetable oils as the only source of lipids, over a period of four weeks. However, the iodine index of the fats used in this last study was much higher than that of the fats given in the previously reported experiments.

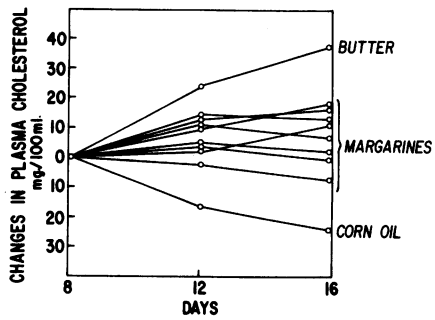


FIG. 1—Average changes in plasma cholesterol values in groups of university students from those observed after eight days on a fat-free diet following substitution of 45% of calories from margarines, corn oil or butter at the expense of an equicaloric amount of carbohydrate. (Reproduced with kind permission from *The American Journal of Clinical Nutrition.*[29])

The study by Beveridge and Connell[29] on the influence of eight different commercial margarines on cholesterolemia is probably one of the most illuminating to date. When added to a fat-free control diet, all margarines with one exception caused a slight elevation of cholesterol levels. Supplementing the same control diet with butter gave rise to a much more pronounced increase in serum cholesterol, whereas corn oil supplements exerted a cholesterol-depressing effect (Fig. 1).

It thus appears that industrial hydrogenation of vegetable oils in the processing of margarines or shortenings somewhat impairs the cholesterol-lowering properties of the natural oil, mainly because of the partial saturation of the polyunsaturated fatty acids. However, it should be remembered that not all margarines have been submitted to the same degree of hydrogenation. Whereas ordinary margarines and shortenings, highly saturated, seem at best neutral with respect to serum cholesterol levels, margarines prepared with a minimum of hydrogenation (the last method mentioned above) which retain a high percentage of the "cis" polyunsaturated fatty acids present in the natural oil are better adjuvants to a "prudent" diet than the others.

As stated previously, in Canada there is only one margarine known to fulfil these criteria. Owing to inadequacy of legislation in Canada, it is difficult for the layman, the physician or even the nutritionist to know the exact fatty acid content of margarines available on the Canadian market. Under the present regulation of the Food and Drug Directorate, labelling is rather unsatisfactory. Article B.09.02 of the Food and Drug legislation only states that if a margarine contains at least 25% of "cis" polyunsaturated fatty acids and if the proportion of saturated fatty acids does not exceed 20%, the label *may* mention: (a) the percentage of total fat as saturated fatty acids and (b) the percentage of total fat as "cis" polyunsaturated fatty acids.

This means that manufacturers of conventional margarines are completely free to indicate the composition on the label or to omit it. Moreover, the statements which appear on the labels of margarines which are rich in polyunsaturated fatty acids are meaningless for the uninformed public, who is obviously inclined to choose the cheapest or the most advertised product instead of the margarines which have most of the properties of the liquid oil. We therefore feel very strongly that action should be taken to implement informative labelling within the Canadian regulations. It should be relatively easy to inform the public of the P/S ratio by stating it on the label.

Conclusion

It is now well recognized that elevating the ratio of dietary polyunsaturated to saturated fats may contribute to the prevention of hypercholesterolemia or reduce serum cholesterol levels. Because of economic pressures and a growing public awareness of the importance of dietary control of serum cholesterol, margarine consumption is constantly increasing at the expense of butter. Is margarine better than butter from the standpoint of preventing hypercholesterolemia? From the previous discussion it can be concluded that "linoleate-rich" margarines can favourably replace butter, but conventional margarines, being substantially more saturated than the original oils, offer little advantage over butter. Their P/S ratio is low and they contain substantial amounts of "trans" fatty acids which seem at best to be neutral with respect to serum cholesterol. However, it should be obvious that little cholesterol-lowering will be achieved if the only dietary modification is substitution of margarine for butter. In order to attain the P/S ratio generally advised for control of serum cholesterol, other steps must be taken, such as the reduction in the consumption of other dairy products (e.g. whole milk, cream and ice cream) and of animal meats, and their substitution by non-shell fish and chicken (without the skin), and the replacement of salad dressings and cooking oils by vegetable oils. The total fat content of the diet should not exceed 40% of the calories and, moreover, caloric intake should be adjusted so as to maintain ideal weight to ensure that a preventive diet is effective. It should also be emphasized that because faulty diet is only one factor in the etiology of cardiovascular disease, modifications of fat-eating patterns with reduction of animal lipids and a concurrent increase in vegetable oil or derivatives are not a panacea and can be of questionable value if relied upon as the sole preventive measure. Nevertheless, a rational, modified-fat diet is an important part of a heart disease prevention program.

Finally, it is the responsibility of every member of the medical profession to inform the public of these facts and to press for adequate legislation that provides the opportunity for every citizen to know exactly what he is getting for his money.

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